Soil Properties and Crop Responses to Alternative Tillage Practices on Grazed Pasture and Cultivated Land in Nigeria

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ABSTRACT

Information on the influence of alternative tillage methods on soil properties when imposed on grazed pasture especially in the rainforest agroecological zone of Nigeria remains fragmentary. The study, aimed at evaluating the responses of soil properties and plant growth parameters (PGP) to maximum (conventional) (MXT), conservation (minimum) (CST) and no-tillage (NOT) was conducted on two adjacent but fenced plots: grazed pasture (GP) and cultivated land (CL). The test crop was maize in a 2 x 3 x 3 completely randomized block experiment. Soil samples collected from 0-10, 10-20 and 20-40cm depths were analysed using standard laboratory procedures and PGP was also monitored for two consecutive cropping seasons. On the GP, for instance, after 2 years under CST, soil compaction indicators like bulk density (BD) and cone index (CI) changed from 1.42 to 1.31 and 4.5 to 3.1 respectively while hydraulic conductivity (Ksat) and infiltration rate (Ir) varied from 61.5 to 50.1 and 73.1 to 56.8, gravimetric moisture content (GMC) changed from 15.9 to 12.4%. Soil organic carbon (SOC) under GP was averaged 13.3% before the experiment but reduced to 1.1, 2.1 and 4.1 respectively under NOT, MXT, and CST after 2 years. Furthermore, Maize yield was 4.7. 4.1 and 3.8 tons/ha for CST, MXT and NOT respectively after the first cropping season but reduced significantly at the end of 2nd year to 3.6, 3.3 and 2.5 tons/ha. However, on the CL, no significant changes in either crop or soil were recorded.

Keywords: grazing, cultivation, conservation tillage, soil compaction, maize yield.

INTRODUCTION

Tillage has generally been described as the mechanical manipulation of the soil aimed at getting a good seedbed for achieving an optimum crop production. Different tillage methods have been widely recognized as a crucial factor influencing soil physical and chemical properties, as well as crop performance (Aina, 1979; Lal, 1986 and Franzleubber and Stuedemann, 2008). In countries where agriculture is a significant contributor to the economy, understanding the effects of tillage practices on soil and crop productivity is essential for sustainable agriculture (Acharya and Sharma, 1994). The development of an appropriate tillage technology for soil and water conservation is particularly relevant in diverse agroecological and climatic zones, especially in light of the increasing impact of climate change (Aina *et al*., 1991; Franzleubber *et al*., 2021).

Several studies have investigated the impacts of tillage practices on soil physical properties. For example, studies by Lal (1986) and Franzleubber (2021) found that no-till and reduced-till practices significantly reduced soil bulk density and increased porosity compared to conventional tillage in southwestern Nigeria. Similarly, a study by Getnet *et al*. (2015) observed that conservation tillage practices improved soil aggregate stability and reduced soil erosion in the rainforest zone of Nigeria. Tillage practices also affect soil chemical properties. For instance, a study by Ezeaku *et al*. (2015) found that no-till and reduced-till practices increased soil organic matter content and nutrient availability compared to conventional tillage in southeastern Nigeria. Other authors, like Busari *et al*. (2015) observed that conservation tillage practices reduced soil nutrient loss and improved soil fertility in the savanna zone of Nigeria. Crop growth parameters and yield are also influenced by tillage practices. A study by da Silva *et al.* (2020) found that no-till and reduced-till practices improved crop yields and water use efficiency compared to conventional tillage in southwestern Nigeria

Different authors have indicated the unhealthy competition and murderous clashes between herdsmen and farmers over land resources that resulted from the impact of climate change in Nigeria (Agboola and Fayiga, 2016). Yet, livestock grazing has been reported as having both positive and negative impact on the soil properties (Ajayi *et al*., 2011). Detailed information on the interactions and influence of different tillage methods when imposed on grazed pasture especially in the rainforest agroecological zone of southwest Nigeria on soil properties remains scanty, fragmentary and tenuous. It is thus the objective of this study to evaluate the changes in soil physical and chemical properties and maize performance on a grazed pasture in Ado Ekiti, Southwest Nigeria.

MATERIALS AND METHODS

The Study Area

The study was carried out on two adjacent fields on the Teaching and Research Farm of the Federal Polytechnic, Ado Ekiti, Ekiti State, Southwest Nigeria. The map of Nigeria showing Ekiti State, The Federal Polytechnic and the experimental site within The Federal Polytechnic campus is presented in Fig 1.

The soil of the study area has been classified as belonging to Ekiti Series and as an Alfisol by Adeosun (2017).

With distinct dry and wet seasons and a modest mean annual rainfall of roughly 1367 mm, Ado Ekiti boasts a humid tropical climate with two peaks to its rainfall patterns. The average yearly temperature in this region is 27 degrees Celsius, with very little variation throughout the year. The two warmest months, February and March, had mean temperatures of 280°C and 290°C, respectively. The months of April through October, which are the rainy season, ` have the highest mean annual relative humidity, which ranges from 50% to 95%. This experiment was conducted between April and October of the years 2021 and 2022.

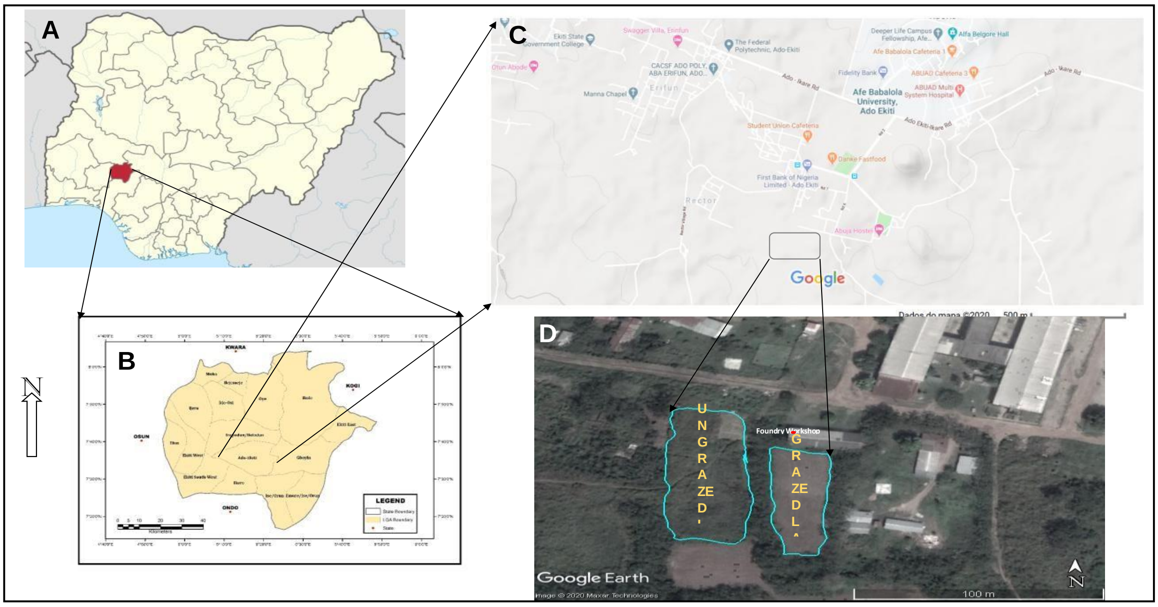

Fig1. Map of Nigeria (A) showing Ekiti State (B), the Federal Polytechnic, Ado Ekiti (C) and the location of the experimental site (D).

Experimental Design

From each of the two adjacent fields, a plot of 80m x 30m size was demarcated for the experiment. The experimental lay out is shown in Fig. 2. Each field consisted of nine subplots, each having three replicates in a randomized tillage treatment. These plots were the site of the field activity, which included planting and soil sampling. The experiment included three different tillage methods with maize as the test crop. The three tillage methods were as defined below:

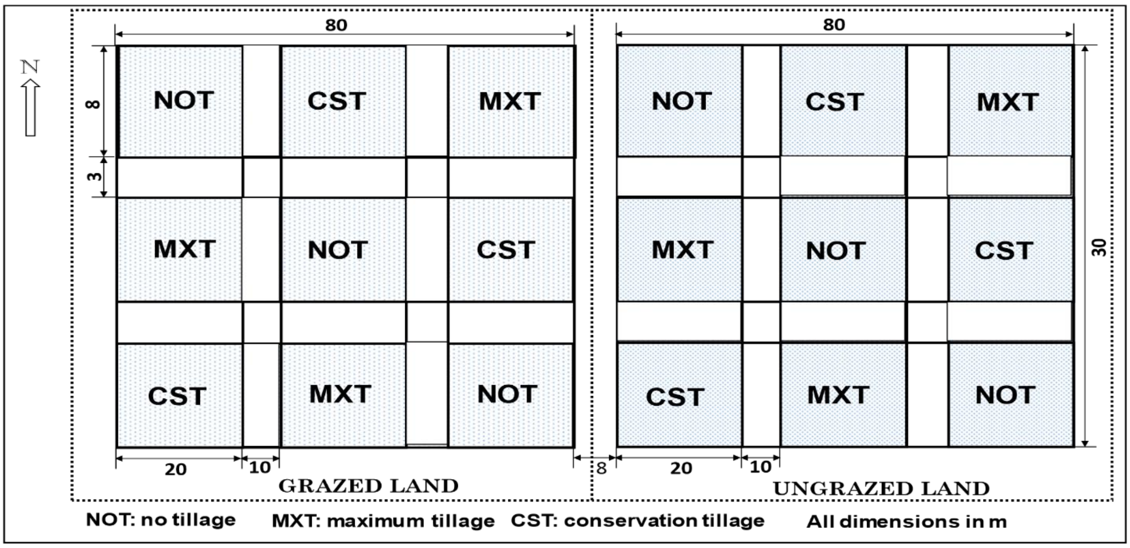

Fig 2. Experimental layout showing the distribution of the treatments.

No Tillage Treatment (NOT)

Plots treated with no-tillage were sprayed with combined herbicides that contained two active chemicals, dimethyl 2,4-D amine and paraquat dichloride, at concentrations of 825 g/L and 297 g/L, respectively, to eradicate weeds. The Knapsack sprayer was filled with a mixture of 30 milliliters of herbicide dimethyl amine and 450 milliliters of paraquat dichloride, which were combined with 14 liters of water. Direct sowing of maize seeds was done on the cleared area.

Conservation Tillage Treatment (CST)

A cutlass was used to sever and remove the weeds from areas intended for conservation tillage treatment. Then, ridges (30 cm high and 45 cm broad) were created with a hoe. A 7.5-tons-per-hectare mulch made of wireweed (Sida acuta) and guinea grass (Panicum maximum) was spread.

Maximum Tillage Treatment (MXT)

The plots underwent one harrowing and two plowings. The tillage depth for both procedures was 15 cm. **Ridges were then made afterwards.**

Soil Sampling

Three different sets of soil samples were collected from three depths: 0 – 10, 10 – 20 and 20 – 40cm on the grazed pasture and cultivated (ungrazed) field. Before the commencement of the experiment, 10 disturbed soil samples were randomly collected from three points each and bulked. The soil samples were put in polythene bags, properly labelled, and immediately transported to the laboratory for analysis.

In October 2021, following the conclusion of the first cropping season, a second set of soil samples was taken. Ten soil samples were taken from each of the nine subplots after the tillage treatment and cropping year/season, for a total of thirty samples from three subplots per tillage treatment. As a result, 90 soil samples were taken from each of the ungrazed field and the grazed pasture. At the end of each tillage experiment, 180 samples in total were collected.

The soil sampling procedures mentioned above were also followed two weeks after the harvesting of the maize crop in 2022, thus marking the conclusion of the experiment.

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Laboratory Studies

(a) Bulk (disturbed) soil samples were air-dried and carefully examined to remove roots, leaves, and other unwanted materials. The samples thereafter were gently crushed and made to pass through 2-mm sieve. One portion of the sieved soil samples was used to determine the following soil physical properties, namely: (i) particle size distribution was determined using hydrometer meter method (Bouyoucos, 1962), (ii) soil dispersion ratio, DR was used to estimate aggregate stability using the method proposed by Middleton (1930). The dispersion ratio (DR) was calculated thus:

$$DR = \frac{\%\ \text{Water dispersible silt} + \text{clay}}{\%\ \text{Calgon dispersible silt} + \text{clay}} \times 100\ \%;$$

and (iii) soil particle density, PD was determined using the volumetric flask method as described by Danielson and Sutherland (1986).

The following soil chemical parameters: soil pH, Total Nitrogen (TN), Soil Organic Carbon (SOC), Available phosphorus (AvP), Electrical conductivity (EC), and Cation Exchange Capacity (CEC) were determined using standard laboratory procedures as outlined in Reeuwijk (2002).

(b) The core (undisturbed) soil samples were used to determine the following physical properties: (i) gravimetric moisture conten**t** (GMC) was obtained from the oven-drying method, (ii) bulk density (BD) was evaluated also by using the oven-dried core soil samples following the methodology described in Blake and Hartge (1986) and saturated hydraulic conductivity (Ksat) was measured using the constant head permeameter method described in EMPRAPA (2011).

Some of the parameters were determined *in situ*, namely: (i) penetration resistance also known as cone index, an indicator of soil strength (CI) measured using a hand-held cone penetrometer (Etrex, USA) while (ii) infiltration rate (Ir) was measured using a double ring infiltrometer.

Statistical Analysis

The classical statistics (maximum, minimum, mean, standard deviation, coefficient of variability, skewness and kurtosis) were calculated for all soil parameters using SAS.

RESULTS AND DISCUSSION

The surface soil properties of the grazed pasture (GP) and the cultivated field (CL) before the tillage treatments were imposed are presented respectively in Tables 1 and 2. While the texture of the grazed GP was sandy loam with 73% sand and clay content of 13%, that of CL was with 85% and 2% sand and clay contents respectively was loamy sand. Bulk density (BD) and cone index (CI), both of which are indicators of soil compaction were high under GP with values that ranged from 1.44 to 1.63 with a mean of 1.4g/cm^3 for BD and 3.4 to 5.3 averaging 4.5kg/cm2 for CI. This level of soil compaction is attributable to the pressure exerted on the soil by cattle hoofs. Soil moisture content under GP varied from 12.4 to 23.2% which is much higher than for CL which was generally below 10%. The other hydraulic properties (Ksat and Ir) averaged 61.5 and 73.1 cm/hr under GP but were 30.1 and 38.4cm/hr for the CL soil. The pH indicated that the grazed soil was weakly acidic (pH 5.5 – 6.8) while the soil on the CL was strongly acidic with pH that ranged from 3.2 to 4.9. Soil organic carbon under GP was expectedly high due to incessant animal dung droppings (maximum of 12.5%) while it was generally below 1% on CL. The CEC, AvP and TN contents of the two soils followed the distributions of the SOC and pH. Meanwhile, at the 20 – 40cm depth, below the plough layer, the texture of the two soils was sandy clay loam (Results not shown).

Table 1. Soil physical and chemical properties of grazed plot

Soil Properties	N	Min	Max	Mean	Std	CV	Skew.	Kurt
Sand %	10	62.5	84.6	72.8	5.1	7.1	0.6	0.8

Silt %	10	3.59	13.8	8.20	1.90	23.17	0.01	-0.7
Clay %	10	44.6	20.30	13.40	3.2	23.88	-0.50	-0.49
BD, g/cm3	10	1.44	1.63	1.42	0.27	19.01	-0.3	-0.52
CI, kg/cm2	10	3.34	5.26	4.45	0.10	2.25	0.58	1.1
GMC %	10	12.4	23.2	15.9	3.19	20.06	1.11	1.10
Ksat, cm/hr	10	49.3	74.90	61.50	3.34	5.43	0.09	-0.10
Ir cm/hr	10	67.25	95.40	73.10	13.80	18.88	0.90	1.11
SOC	10	3.90	12.50	7.55	1.15	15.23	0.10	-0.20
PH	10	5.52	6.85	5.71	0.09	1.57	0.18	-0.95
CEC	10	1.19	5.31	3.40	0.99	29.18	0.88	0.30
AvP	10	0.26	1.01	1.02	0.10	9.81	-0.63	0.16
TN	10	0.33	0.59	0.22	0.05	22.73	0.23	0.11

Table 2: Soil physical and chemical properties of cultivated land

Soil Properties	N	Min	Max	Mean	Std	CV	Skew.	Kurt.
Sand %	10	79.42	93.20	85.43	1.54	1.80	0.19	0.80
Silt %	10	3.99	4.06	3.89	0.87	22.36	-0.90	-0.50
Clay %	10	2.99	3.21	2.12	0.95	44.81	-0.29	-0.80
BD, g/cm3	10	1.22	1.36	1.26	0.01	0.79	0.05	-0.45
Cl	10	1.20	1.35	1.29	0.04	3.10	0.09	-0.25
GMC	10	4.35	9.60	7.49	1.11	14.82	1.10	1.100
Ir	10	28.7	39.5	38.40	4.16	10.83	0.32	-0.30
Ksat cm/hr	10	19.17	35.12	30.08	0.99	3.29	0.20	1.00
SOC	10	0.17	1.16	0.65	0.02	3.07	0.25	0.21
pH	10	3.25	4.90	4.34	0.15	3.46	0-.01	-0.99
AvP	10	0.01	1.13	0.97	0.26	26.81	-0.50	-0.80
TN	10	0.01	0.01	0.99	0.11	11.11	0.10	-0.40
CEC	10	0.01	0.03	0.03	0.08	266.6	0.40	-0.75

Effects of Tillage on Soil Properties of Grazed Pasture

Table 3 presents the impact of alternative tillage treatments at three depths and on selected soil parameters of the grazed pasture at the end of the first cropping season. Under no-tillage (NOT), soil organic carbon (SOC) at the 0 – 10 cm which was as high as 12.5% dropped and now stands at 3.8%. On the other hand, maximum tillage reduced SOC to 2.3% and conservation tillage (CST) got SOC down to 4.6%. At the end of the second cropping season, the SOC under CST dropped somewhat from 4.6 to 4.1%, while under NOT and MXT, it dropped to

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1.1% and 2.1% respectively. A comparable pattern of SOC loss was noted throughout the profile. Aina (1979), Lal (1986), Ajayi and Chokor (2013), and Getnet *et al*. (2015) have documented the decline in soil organic carbon resulting from ongoing tillage. Some explanations for the drop in SOC offered by these authors were that in addition to crop uptake, processes such as leaching, organic matter mineralization, and soil erosion by water; all of which are occasioned by climatic forces such as stormy rainfall and high temperature, could have accounted for the SOC loss.

Furthermore, the Table (3) shows changes in the hydraulic properties of the grazed soil. For example, gravimetric moisture content under NOT decreased from 13.3% to 12.6% at 0–10 cm deep following the first cropping season, but GMC was 10.6% and 14.2% for CST and MXT, respectively. The infiltration rates for NOT and CST were 72 and 78 cm/hr, respectively, however they differed significantly from the 62 cm/hr for MXT. Ksat was 70.3 cm/hr under CST and 68.6 cm/hr under no-tillage; both values were significantly from MXT's Ir of 58.2 cm/hr. With a high DR of 71.1%, soil aggregate stability was lowest under MXT. Compared to the DR values of soils under NOT and CST, which were 42.3 and 48.7%, respectively, this was substantially greater ($p < 0.5$). As to Rasheed's (2016) findings, aggregate stability is moderate in soils with DR less than 50% and low in soils with DR greater than 50%. Therefore, it would seem that NOT and CST are in favour of soil aggregate stability over tillage techniques that require the use of large equipment like tractors and related tools. Cone index (CI) assessed the resistance of soil to root penetration; with MXT, the CI was 1.15 kg/cm2, significantly higher ($p < 0.05$) than 1.32 and 1.43 kg/cm2 obtained under CST and MXT, respectively. The grazed plot's soil acidity under each tillage technique was moderately high, with a pH of 5.2 at the top 10 cm. For MXT, CST, and NOT, the CEC varied from 1.17, 1.44, and 1.57 cmol/kg, respectively. In most cases, the electrical conductivity was more than 10 S/cm. It has been observed that the chemical characteristics of soil under agriculture decrease in terms of both pH and CEC (Adepetu, 2014; Awe *et al*., 2018).

At the depths of 10–20 and 20–40 cm, the trend in soil behaviour shown under the various tillage treatments was equally discernible in the top 10 cm of soil layers.

Table 3. Soil properties of GP under alternative tillage practices at three depths after the first (2021) cropping season

Depths	N (cm)	SOC (%)	GMC (%)	BD (g/cm3)	Ir (cm/hr)	Ksat, (cm/h)	DR (%)	pH	CEC (cmol/kg	CI (kg/cm2)	EC (S/cm)
NO TILLAGE											
0 –10	10	3.8	12.6	1.46	78.3	68.6	42.3	5.2	1.57	4.43	15.5
10 –20	10	3.3	12.2	1.41	N.A.	67.2	49.8	5.3	1.73	4.52	13.4
20 –40	10	3.1	10.2	1.42	N.A.	72.6	52.5	5.7	1.81	4.65	14.7
CONSERVATION TILLAGE											
0 – 10	10	4.6	14.2	1.38	72.7	70.3	48.7	5.4	1.44	4.32	17.3
10 –20	10	5.2	14.4	1.34	N.A.	69.1	48.2	5.1	1.67	4.41	12.6
20 –40	10	5.5	12.1	1.40	N.A.	68.5	46.0	5.3	1.65	4.48	14.9
MAXIMUM TILLAGE											
0 – 10	10	2.3	10.6	1.41	62.2	58.2	71.1	5.2	1.17	1.15	11.2
10 –20	10	2.8	9.6	1.40	N.A.	62.5	67.5	4.8	1.25	1.23	11.8
20 –40	10	2.6	11.0	1.43	N.A.	55.2	72.9	4.6	1.82	4.61	13.7

Table 4 shows the changes in soil parameters under the various tillage treatments at the end of the experiment, which occurs after the second cropping season on the grazed plot in 2022. Changes in the chemical, physical,

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and hydraulic parameters showed further degradation of soil fertility. As demonstrated by the higher bulk densities (1.48 and 1.51 g/cm3) and cone indices (1.45 and 1.21 kg/cm2) under NOT and MXT, respectively, compared to the results obtained after the first cropping season, the level of soil compaction increased, and the soil under CST was further loosened as demonstrated by the lower BD (1.31 g/cm3) and CI (1.11 kg/cm2). While aggregate stability improved under the other two tillage treatments, it further declined with MXT (78.8%). The moisture content at field capacity under CST was 12.4%, far greater than the moisture level under NOT and MXT, which were both less than 10%. This outcome appears to have been caused by the application of mulching materials on the barely tilled soil under CST, as da Silva *et al.* (2020) have also noted.

As earlier noted, due to crop uptake, leaching, and mineralization brought on by exposure to climatic influences, the soils under the three tillage treatments had even lower levels of soil organic carbon, pH, and cation exchange capacity. Under NOT and MXT, the top 10 cm of soil's SOC had decreased by almost 50%, but under CST, it had decreased by just 11%. This observation may have something to do with mulching's restorative properties.

Table 4: Soil properties of GP under alternative tillage methods at three depths after second (2022) cropping season.

DEPTN	SO (cm)	HSC (%)	GMC (%)	BD (%)	Ir (cm/hr)	Ksat (cm/hr)	DR (%)	pH	CEC (cmol/ kg)	CI (kg/cm2)	EC (S/cm)
NO TILLAGE											
0 – 10	10	2.1	9.4	1.48	56.8	50.1	41.4	4.9	1.04	4.45	14.6
10 – 20	10	1.3	8.5	1.51	-	48.2	43.4	4.6	1.11	4.55	13.2
20 – 40	10	1.0	10.3	1.44	-	55.4	50.6	5.0	1.60	4.62	12.4
CONSERVATION TILLAGE											
0 – 10	10	4.1	12.4	1.31	66.6	69.4	52.7	5.1	1.12	3.11	12.7
10 – 20	10	4.8	11.4	1.31	-	67.7	50.1	4.8	1.18	3.21	13.5
20 – 40	10	5.1	11.2	1.35	-	67.8	57.6	5.4	1.36	4.23	11.6
MAXIMUM TILLAGE											
0 – 10	10	1.1	9.7	1.51	50.1	40.4	78.8	4.8	0.8	2.21	18.2
10 – 20	10	1.1	8.1	1.49	-	47.5	72.1	4.8	0.8	3.12	10.5
20 – 40	10	1.1	8.8	1.48	-	42.3	74.1	4.8	0.8	4.44	10.8

Table 3 shows the effects of various tillage techniques on the soil parameters of the continually cultivated but ungrazed plot following the 2021 first cropping year. In general, the chemical, hydraulic, and physical qualities of the soil did not seem to have improved much. For example, there was no discernible variation in the way any of the tillage treatments affected any of the chemical qualities of the soil. All of the soils' bulk densities stayed at or above 1.7 g/cm3, and their CIs were over 1.3 kg/cm2, both of which pointed to some degree of soil compaction. GMC was less than 10% in every soil. Under NOT and MXT, infiltration rates were less than 40 cm/hr, however, under CST, they were somewhat higher at 40.7 cm/hr. Ksat was less than 40cm/hr for every treatment.

Table 5: Soil properties of CL under different tillage methods at three depths after first (2021) cropping season

DEPTHS	N (cm)	SOC	GMC	BD	Ir	Ksat	DR	pH	CEC	CI	EC
NO TILLAGE											

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0 – 10	10	0.66	9.5	1.75	37.7	36.4	81.7	4.6	0.22	1.37	1.5
10 – 20	10	0.65	9.2	1.73	-	38.8	77.3	4.6	0.22	1.35	2.5
20 – 40	0.69	8.6	1.76	-	40.2	78.5	4.7	0.25	1.46	2.6	
CONSERVAT TILLA											
0 – 10	10	0.72	9.7	1.71	40.7	38.8	78.2	4.8	0.27	1.33	1.7
10 – 20	10	0.71	9.7	1.71	-	37.6	72.4	4.7	0.28	1.37	1.6
20 – 40	10	0.83	9.6	1.72	-	36.7	71.3	4.8	0.28	1.47	1.4
MAXIMUM TILLAGE											
0 – 10	10	0.44	8.8	1.75	34.2	34.8	88.4	4.5	0.14	1.32	0.7
10 – 20	10	0.40	8.6	1.77	-	38.1	89.3	4.5	0.15	1.34	0.5
20 – 40	10	0.46	7.6	1.78	-	36.3	94.7	4.8	0.12	1.47	0.3

Table 4 shows the alterations in soil characteristics on an ungrazed but cultivated plot under various tillage techniques following two cropping years. Following two years of applying the three tillage techniques, there was basically no discernible difference in the soil characteristics as a result of any of the treatments, suggesting that the responses of the soil properties to these treatments were marginal and sluggish. For example, SOC stayed low overall, at less than 1% for all three soils at all three depths. Likewise, under NOT, CST, and MXT, CEC has further decreased to 0.86, 1.2, and 0.6 cmol/kg, respectively. All of the soils had considerable acidity, as evidenced by the pH values, which were 4.8 for NOT and CST soils and 4.6 for MXT. Every soil treated with any of the three tillage techniques had an electrical conductivity (EC) of less than 10. An example of how soil hydraulic characteristics behaved differently is seen in the increased levels of GWC, Ir, and Ksat, particularly under CST. The soil treated with CST had a GWC that was significantly higher ($p < 0.05$) than the soils treated with NOT and MXT, which both had GWCs of less than 10%. The soil under CST exhibited a considerably greater ($p < 0.05$) infiltration rate (47.9 cm/hr) and saturated hydraulic conductivity (55.3 cm/hr) in comparison to that under NOT and MXT. Soil aggregate stability (assessed by the dispersion ratio, or DR) has improved under the NOT and MXT, as seen by a considerably lower DR ($p < 0.05$). Applying decreased tillage and no-till in conjunction with mulch application resulted in a measurable increase in the hydraulic characteristics over the course of two years. The aforementioned findings thus seem to indicate that the two-year study period was too short for the effects of no-tillage and conservation tillage practices to be noticeable, and that the beneficial effects on soil chemical properties under long-term cultivation would only be noticeable in the long run, possibly after five years as reported by Heenan *et al*. (2004). This finding might be particularly true for tropical alfisols, such as the one under study, which have been shown by a number of writers (Aina, 1991 and Getnet *et al*., 2015) to have brittle structural integrity and low fertility at birth. In fact, Getnet *et al*. (2015) discovered that before and after tillage, changes in a tropical soil's chemical parameters, such as its pH, organic matter content, and nitrogen percentage, were statistically negligible for all treatments.

Table 6. Soil properties of CL under different tillage methods at three depths after the second (2022) cropping season

DEPTHS (cm)	N	SOC (%)	GMC	BD	Ir	Ksat	DR	pH	CEC	CI
NO TILLAGE 0-10	10	0.57	9.4	1.66	40.1	37.2	73.1	4.4	0.11	1.46
10-20	10	0.59	9.6	1.65	-	35.6	76.3	4.5	0.13	1.45
20-40	10	0.59	9.5	1.71	-	38.9	78.9	4.6	0.15	1.45

CONSERVATION TILLAGE										
0-10	10	0.5	12.7	1.58	47.9	55.3	67.5	4.8	0.23	1.21
10-20	10	0.93	9.5	1.65	-	50.5	70.1	4.8	0.31	1.31
20-40	10	0.93 -	9.8	1.71	-	48.8	70.2	4.8	0.23	1.35
MAXIMUM TILLAGE										
0-10	10	0.64	8.6	1.76	36.4	39.4	96.9	4.4	0.1	1.54
10-20	10	0.71	8.6	1.75	-	40.1	91.3	4.4	0.1	1.49
20-40	10	0.70	8.5	1.78	-	40.8	95.2	4.6	0.1	1.53

Effects of Grazing on Crop Performance

Table 5 provides an overview of how crop response to livestock grazing has changed. Grazing caused a substantial change ($p < 0.05$) in all the parameters (leaf number, leaf area index, plant height, and crop production) in the two cropping years (2021 and 2022). For instance, it was noted that although there was a notable drop in yield from 4.3 to 3.1 tons/ha in just one cropping year (2021–2022), this may be explained by elements like crop uptake of nutrients and organic matter (Adepetu, 2014). After plowing techniques were refined, the soil became more vulnerable to weather extremes such as intense rains, which also led to the leaching of plant nutrients.

Table 7. Maize Growth Parameters of GP and CL for 2021 and 2022

Crop performance parameters	2021		2022		2021	2022
	Grazed	Cultivated	Grazed	Cultivated	LSD (0.05) A	LSD (0.05) B
Leaf Number at 6 WAP	12	8	12	9	2	2
Leaf area index at 6 WAP	4500	620	3420	1005	700	445
Plant height (cm) at 10 WAP	205	68	200	80	44	64
Crop yield tons/ha	4.3	0.3	3.1	0.3	1.6	1.4

Effects of Tillage Methods on Crop Performance

According to Table 6, in the first cropping year of 2021, there were nine leaves at two weeks after planting (2WAP) for the three tillage practices on the grazed soil and four on the ungrazed land. There was no discernible difference between the three tillage treatments until the sixth week, at which point all of the permanent leaves had been generated. In the second cropping year (2022), the outcome is marginally different. On the grazed soil under conservation tillage, the number of leaves increased from 8 to 12 at 2WAP to 6WAP, whereas on the ungrazed soil, it decreased from 5 to 8 (Table 8).

The Leaf Area Index (LAI) was linked to variations in the number of leaves in maize (Table 10). The LAI was considerably altered ($p < 0.05$), but the leaf number was not. For instance, under the grazed soil, the LAI of maize at 2WAP was NOT > CST > MXT. This result suggests that tillage had an impact on leaf size or the overall surface area available for photosynthesis. This maize performance was ascribed by Lal (1986) and Getnet *et al*. (2015) to the way the seedbed configuration and mulching alter the crop's response to a varied response to the soil temperature regime.

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In the first cropping year (2021) on the grazed plot, the plant height of maize was in the following order ten weeks after planting/sowing: conservation tillage = maximum tillage > No-tillage. Plant height under no-tillage treatment and the tilled soils at maturity differed significantly ($p < 0.05$) in the second year (Table 6).

The relationship between grazing and tillage treatments affects maize yield. The best yield of 4.7 tons/ha was achieved under conservation tillage in the first cropping year (Table 12). The three tillage treatments did not significantly differ ($p < 0.05$), but the maize yield on the grazed pasture was nevertheless high overall, at 3.8 tons/ha under no-tillage and 4.12 tons/ha with maximal tillage. Compared to the first cropping year (2021), maize yield in the second cropping year was significantly lower. Mulching and seedbed preparation led to the desired yield, which was reached in the following order: conservation tillage > maximum tillage > no-tillage. The relationship between grazing and tillage treatments affects maize yield. The best yield of 4.7 tons/ha was achieved under conservation tillage in the first cropping year (Table 12). The three tillage treatments did not significantly differ ($p < 0.05$), but the maize yield on the grazed pasture was nevertheless high overall, at 3.8 tons/ha under no-tillage and 4.12 tons/ha with maximum tillage. Compared to the first cropping year (2021), maize yield in the second cropping year seedbed preparation led to the desired yield, which was reached in the following order: conservation tillage > maximum tillage > no-tillage.

Table 8. Number of leaves under different tillage treatments on the grazed soil during two cropping years (2021 and 2022)

	2WAP	4WAP	6WAP
No-Tillage	9 (6)	12 (9)	12 (10)
Conservation Tillage	9 (8)	12 (10)	12 (12)
Maximum Tillage	9 (8)	12 (10)	12 (10)
LSD (0.05)	2 (2)	2 (2)	2 (2)

Note: Figures in brackets are for 2022

Table 9: Leaf number under different tillage treatments on the cultivated plot during two cropping years (2021 and 2022)

TILLAGE TREATMENTS	2WAP	4WAP	6WAP
No-Tillage	4 (6)	6 (8)	8 (10)
Conservation Tillage	4 (6)	6 (8)	8 (10)
Maximum Tillage	4 (5)	6 (6)	8 (8)
LSD (0.05)	2 (2)	2 (2)	2 (2)

Table 10: Leaf Area Index under different tillage treatments during two cropping years (2021 and 2022)

TILLAGE TREATMENTS				Cropping Years				
			2021				2022	
	2WAP	4WAP	8WAP	10WAP	2WAP	4WAP	8WAP	10WAP
No Tillage	650 (274)	2812 (503)	2888 (650)	3012 (724)	606 (268)	2616 (487)	2667 (586)	2802 (694)

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Conservation Tillage	750 (280)	2787 (560)	2903 (635)	3107 (766)	780 (295)	2802 (576)	2890 (684)	2905 (801)
Maximum Tillage	888 (241)	2818 (487)	2986 (508)	3208 (524)	796 (235)	2785 (470)	2897 (481)	3108 (509)
LSD (0.05)	53 (44)	77 (69)	68 (34)	10 (252)	34 (61)	195 (10)	233 (178)	117 (120)

NB: Leaf Area Index of ungrazed soil is provided in parenthesis

Table 11: Plant heights under different tillage methods on the grazed and cultivated soils during two cropping years (2021 and 2022)

TILLAGE TREATMENTS	Cropping Years															
	2021							2022								
	Grazed (cm)				Cultivated (cm)			Grazed (cm)				Cultivated (cm)				
	2W AP	4W AP	6W AP	10W AP	2W AP	4W AP	6W AP	10 WAP	2W AP	4W AP	6W AP	10 WAP	2W AP	4W AP	6W AP	10 WAP
No-Tillage	30	68	90	96	10	20	30	63	30	64	86	90	10	24	30	82
Conservation Tillage	32	74	94	210	14	24	36	70	32	78	82	205	15	28	42	94
Maximum Tillage	34	72	92	210	10	23	32	72	32	70	80	201	10	20	36	66
LSD (0.05)	6	5	10	25	3	4	10	5	2	9	10	20	3	10	10	15

Table 12: Maize yield affected by different tillage treatments on the grazed plot during two cropping years

TILLAGE TREATMENTS	**Cropping Years**	
	2021	2022
	tons/ha	tons/ha
No-Tillage	3.81	2.45
Conservation Tillage	4.70	3.62
Maximum Tillage	4.12	3.27
LSD (0.05)	0.43	0.55

Table 13: Maize yield affected by different tillage treatments on cultivated plot during two cropping years

TILLAGE TREATMENTS	Cropping Years	
	2021 (tons/ha)	2022 (tons/ha)
No-Tillage	0.18	0.24
Conservation Tillage	0.21	0.21

Maximum Tillage	0.17	0.15
LSD (0.05)	0.03	0.05

SUMMARY AND CONCLUSION

The soils of the two fields; grazed and cultivated, were either sandy loam or loamy sand at the surface with a clayey subsoil. With significantly higher bulk density and cone index, the grazed soil exhibited some forms of soil degradation. Infiltration rate, hydraulic conductivity and water retention of the grazed soil were positively impacted by the increased organic matter deposit by the grazing cattle. Moreover, improved soil nutrients occasioned by the heavy organic matter in conjunction with the conservation tillage practices resulted in higher yield on the grazed soil.

For sustainable crop production on these heavily weathered and weakly structured soils, with inherently low fertility, and similar soils under the same agroecological zone after being opened up to mechanized tillage and continuous cultivation there is need to practise minimum tillage with mulching as this will prevent soil erosion with its attendant nutrient loss as is commonly experienced under stormy rainfalls that characterize the study area.

Given the above results therefore, there is a need for the adoption of integrated farming practices involving the incorporation of minimal grazing of livestock to continuous cropping of the same land thereby encouraging organic manure build up that guarantees soil aggregate stability and nutrient supply and therefore improved crop yield.

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